CONCURRENT SCHEDULE PERFORMANCE WITH YOUNG INFANTS

An abstract of a Thesis by
Elliott J. Bonem
October 1980
Drake University
Advisor: Larry A. Alferink

The problem. In operant research on infant conditioning, extinction sessions often are conducted in demonstrating schedule control over the response. However, extinction sessions are often accompanied by disruptive behaviors which terminate experimental sessions. Concurrent reinforcement schedules provide a methodology for demonstrating schedule control over the response without relying on extinction sessions. The purpose of this study is to determine whether infant responding can be acquired, maintained, and systematically controlled by concurrent reinforcement schedule contingencies.

Procedure. During daily sessions, three young infants were exposed to several concurrent variable-interval schedules. A mobile rotation, contingent on a foot kick, was occasionally available on each schedule component. Head turns served as the changeover response. Relative time allocation was assessed as was matching between the logarithm of time (and response) ratios and log-reinforcement ratios.

Findings. Without relying on extinction sessions, schedule control was demonstrated for all infants. The proportion of time spent in a given schedule component systematically varied as the programmed availability of contingent mobile movement was varied. By tending to allocate responses and time equally between the two schedule components, irrespective of programmed reinforcement, all infants undermatched and showed a positive bias for the richer schedule component.

Conclusion. Concurrent reinforcement schedules provide a methodology for demonstrating systematic control over infant responding. Although the matching relationship seems to generalize to young infants, the variables which are the source of undermatching and bias have not been identified.

Recommendations. To gain better experimental control over infant responding, the sources of bias and undermatching must be identified. For example, future research could determine whether bias results from using qualitatively different reinforcers, or whether better matching results from incorporating a changeover delay.

CONCURRENT SCHEDULE PERFORMANCE WITH YOUNG INFANTS

A Thesis

Presented to

The School of Graduate Studies

Drake University

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

---

by

Elliott J. Bonem

October 1980

CONCURRENT SCHEDULE PERFORMANCE WITH YOUNG INFANTS

by

Elliott J. Bonem

Approved by Committee:

Larry A. Alferink

Dr. Larry A. Alferink, Chairperson

W Scott Wood

Dr. W. Scott Wood

Gene G. Lucas

Dr. Gene Lucas

Earle L Campbell

Dean of the School of Graduate Studies

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION AND REVIEW OF THE LITERATURE

When the relative frequency of responding on one component of a concurrent variable interval schedule (conc VI VI) depends on the relative frequency of reinforcement for responses on that alternative, the relationship which results is described as matching (Herrnstein, 1961). This matching relationship occurs when the relative distribution of responses or time between each schedule alternative approximately equals the relative distribution of obtained reinforcement on the schedules (Herrnstein, 1961, 1970). The matching law is a symbolic description of this relationship which, in its most rudimentary form, is expressed by the equation: $\frac{R_a}{R_a + R_b} = \frac{r_a}{r_a + r_b}$, where R is response rate and r is reinforcement rate for operants a and b (Herrnstein, 1970). The matching law is relatively descriptive of the actual schedule performance of an organism given an experimental procedure which utilizes a changeover delay (COD) of sufficient duration (Brownstein & Pliskoff, 1968; Herrnstein, 1961; Shull & Pliskoff, 1967) and an experimental design which adequately controls for the order effects of reinforcement schedules (deVilliers, 1977).

Although the majority of research on the matching law has been conducted with pigeons, with key pecking maintained by food reinforcement, the generality of the matching

law has been extended to various species, reinforcers, operants, and schedules (c.f., deVilliers, 1977). The matching law has been found to be descriptive of the performance of human subjects in numerous choice studies (Baum, 1975; Bradshaw, Szabadi, & Bevan, 1976; Moffatt & Koch, 1973; Schroeder & Holland, 1969). However, the generality of the matching law has yet to be extended to the schedule performance of human infants.

Since the early 1960's, an increasing number of studies have reported control over infant responding using schedules of continuous reinforcement (c.f., Huselbus, 1973). Even though recent infant research has been directed towards the refinement of experimental procedures and designs, most infant conditioning studies still use simple, basic schedules (e.g. conjugate reinforcement) to increase the frequency of the operant(s) of interest (e.g., Rovee-Collier & Gekoski, 1979). This continued reliance on simple schedules of reinforcement in infant research is somewhat perplexing. Although infants acquire responding quickly on simple schedules, subsequent extinction sessions necessary for the demonstration of internal validity are often accompanied by "disruptive" adjunctive behaviors (e.g. crying) which effectively terminate experimental sessions (c.f., Huselbus, 1973).

In one of the only published infant conditioning studies utilizing a free operant paradigm within a single

subject design, Sheppard (1969) attempted to demonstrate schedule control over responding by avoiding the use of extinction sessions. Two multiple schedules (Mult FR 3 DRO and Mult FR 3 Noncontingent Reinforcement) were initially investigated, each schedule failing to establish differential responding in the infant. Apparently, both the DRO and noncontingent schedule components "functionally resembled experimental extinction" (Sheppard, 1969, p. 43). However, upon a subsequent schedule manipulation, Sheppard was able to demonstrate differential control over responding by intermittently reinforcing two responses (vocalizations and leg kicks) in a disjunctive discrimination schedule where the S^D for one response was the S^Δ for the other response.

The results of Sheppard's (1969) study suggest that infant behavior may be sensitive to the complex contingencies created in compound schedules of reinforcement. The use of one such compound schedule, a concurrent schedule, would provide a methodology whereby one rich schedule component could be continuously available, thereby avoiding extinction sessions which have repeatedly disrupted infant responding.

The present experiment was designed to provide answers to two questions: (a) Would infants demonstrate response acquisition and maintenance on concurrent schedules of reinforcement? And (b) if so, would infant responding

conform to the matching relationship repeatedly demonstrated in studies of older humans and other species? Such an investigation of concurrent performances may also provide a methodology for investigating infant conditioning without relying on extinction sessions to demonstrate control over the response.

CHAPTER II

METHOD

Subjects

Three normal human infants served as subjects. At the onset of the study, the infants ranged in age from 5 to 6 weeks. Meghan, Tera, and Matthew were recruited through published birth announcements.

Setting

Sessions were conducted in a small observation room located in the Center for Human Development. A modified wooden box measuring 94 cm long by 48 cm high by 65 cm wide served as the experimental compartment. The bottom of the compartment was covered with a 3 cm pad of foam rubber, both to cushion the infant and to prevent the infant from sliding away from the response manipulandum. During Tera's final 4 sessions, a white plywood sheet was placed along the left side of the compartment in order to prevent the infant from turning from a supine to a prone position.

All distracting stimuli were removed from the room, and a three-sided partition surrounded the chamber. During all experimental sessions an air-conditioner was continuously run both to produce white noise and to maintain room temperature at approximately 72° Fahrenheit.

Apparatus

Contingent movement of a modified mobile apparatus (Watson & Ramey, 1972) was used as the reinforcer. A mobile stand was positioned such that an L-shaped suspension bar was centrally located above the experimental compartment. The mobile, consisting of four colored styrofoam spheres in a fixed cluster, hung from the suspension bar such that the bottom sphere of the cluster was positioned 25 to 30 cm above the infant's upper abdomen. Located above the suspension bar was a sound attenuated box containing a small electric motor (Dayton shaded pole break gearmotor, stock number 3M231). The motor, when activated by an electrical pulse, rotated the sphere cluster at 8 rpm for 1.5 seconds.

The front panel of the experimental compartment contained 2 hinged plexiglass response panels, each measuring 6.5 cm high by 13 cm wide. Mounted behind each panel was a microswitch which produced a brief auditory click when activated. The microswitches had to be released and depressed again for another response to be registered. When both microswitches were depressed simultaneously, only one response was registered.

The back of the chamber contained a special changeover response (COR) manipulandum (Lund, 1976). A sturdy plexiglass headpiece, designed to cradle the infant's head, protruded from the back panel of the compartment via an extension bar. The headpiece was designed such that any

headturn of more than 10° to the right or left activated the COR circuitry. S^Ds associated with each schedule component, consisting of a tone of either 1200 hz or 900 hz, were presented via a speaker mounted above the COR circuitry on the back panel.

All experimental events were controlled by solid state equipment (BRS-LVE) located in a room adjacent to the experimental compartment. Data were recorded on impulse counters.

Procedure

An adaptation procedure was used to minimize the fussing behavior each infant was expected to emit when placed in the experimental compartment (Weisberg, 1969). For the first four sessions (five for Meghan), the parent placed the infant in the experimental compartment and remained nearby. No mobile was present and no experimental contingencies were in effect. Solid state equipment recorded all foot kicks and head turns.

Prior to the onset of each session, the infant was brought to the experimental compartment where (s)he was placed in a supine position. The infant's head was centered in the headpiece, and the infant's feet were rested lightly against the response panels. When the infant was resting comfortably (e.g. not crying), the experimenter and parent left the room. The session began when the experimenter

activated the response circuitry in the adjoining observation room. A one way mirror and intercom system permitted continual monitoring of the infant.

Reinforcement was scheduled utilizing a modified version of Findley's (1958) changeover key concurrent procedure. Responses on the foot kick manipulandum were occasionally followed by 1.5 seconds of mobile rotation. A single right or left head turn, designated the changeover response, altered the pitch of the constant tone and the available schedule on the response panels. For Tera and Matthew, when the tone was 1200 hz, responses were reinforced on the constant schedule component; when the tone was 900 hz, responses were reinforced on the changed schedule component. The tones paired with each component were reversed for Meghan. The two schedules were concurrent since the VI timer for one schedule ran during the period the infant had access to the other VI schedule. In the course of the study, the interval lengths associated with each schedule component were systematically varied. Table 1 lists the values of the VI schedules (in seconds) and the order of their presentation.

For each infant, experimental sessions were held every weekday for 10 minutes. However, if the infant cried continuously for more than five minutes, or fell asleep, the experimental session was terminated and the data discarded.

Table 1

Concurrent Schedule Pairs, the S^D Associated with Each Concurrent Schedule Component, and the Number of Sessions Each Infant was Exposed to Each Pair

Subject	Tone Frequency		Sessions
	900 hz	1200 hz	
Meghan	VI 10 sec	VI 10 sec	9
	VI 10 sec	VI 5 sec	6
	VI 10 sec	VI 20 sec	5
	VI 10 sec	VI 40 sec	7
Tera	VI 10 sec	VI 10 sec	9
	VI 5 sec	VI 10 sec	9
	VI 20 sec	VI 10 sec	5
	VI 5 sec	VI 10 sec	4
Matthew	VI 10 sec	VI 10 sec	11
	VI 5 sec	VI 10 sec	6
	VI 20 sec	VI 10 sec	5
	VI 5 sec	VI 10 sec	7

Response Recording

In order to investigate matching, the following data were automatically recorded: 1) total number of foot kick responses emitted while the constant schedule component was in effect; 2) total number of foot kick responses emitted while the changed schedule component was in effect; 3) total number of changeover responses; 4) total number of reinforcers presented while the constant schedule component was in effect; 5) total number of reinforcers presented while the changed schedule component was in effect; 6) total amount of time the constant schedule component was available on the response manipulandum; and 7) the total time the changed schedule component was available on the response manipulandum.

CHAPTER III

RESULTS

Tables 2, 3, and 4 summarize the sequence of experimental conditions and overall performance measures for Meghan, Tera, and Matthew, respectively. All of the data presented are means derived from performance during the final five sessions of a condition, with the exception of the adaptation condition for Tera and Matthew, and the final conc VI 10 sec VI 5 sec condition for Tera, all of which represent conditions in which only four sessions were conducted. As can be seen from these tables, all infants emitted the changeover response (head turn) and operant response (foot kick) during the adaptation sessions. Surprisingly, local response rates emitted by each infant during the adaptation condition remained relatively invariant across all conditions.

Changeover Responding

Figure 1 shows the changeover response data for the three infants. The total number of head turns each infant emitted are presented for the final five days of each condition, except when less than five days of data were collected. Only four adaptation sessions were conducted with Tera and Matthew, and only four sessions were conducted with Tera in the final conc VI 10 sec VI 5 sec condition.

Table 2

Summary of the Results for Meghan in Each Condition Including Schedule Parameters, Changeover Responses, Time Spent Responding in Each Component, Number of Responses Emitted in Each Component, Number of Delivered Reinforcements in Each Component, and Local Response Rate in Each Component. All data are means of the last five days of exposure to the conditions.

Meghan

	Schedule Parameters in Seconds				
	Adaptation	VI 10 VI 10	VI 10 VI 5	VI 10 VI 20	VI 10 VI 40
Changeover responses	18	29	44	38	42
Time (seconds)					
constant	126	330	234	368	359
changed	214	270	366	232	241
Responses					
constant	42	59	111	192	121
changed	69	49	152	109	70
Reinforcements					
constant	--	19	18	26	25
changed	--	14	45	11	9
Local response rate: resp/min					
constant	20.0	10.7	28.5	31.3	20.2
changed	19.3	10.9	24.8	28.2	17.4

Table 3

Summary of the Results for Tera in Each Condition Including Schedule Parameters, Changeover Responses, Time Spent Responding in Each Component, Number of Responses Emitted in Each Component, Number of delivered Reinforcements in Each Component, and Local Response Rate in Each Component. All data are means of the last five days of exposure to the conditions except for the adaptation sessions and the last conc VI 10 sec VI 5 sec condition, which are the means of the last four days of exposure.

Tera

	Schedule Parameters in Seconds				
	Adaptation	VI 10 VI 10	VI 10 VI 5	VI 10 VI 20	VI 10 VI 5
Changeover responses	23	20	31	24	70
Time (seconds)					
constant	256	289	140	396	239
changed	207	292	460	204	361
Responses					
constant	93	155	78	160	69
changed	69	164	248	66	114
Reinforcements					
constant	--	23	10	21	15
changed	--	28	64	10	40
Local response rate: resp/min					
constant	21.8	32.2	33.4	24.2	17.3
changed	20.0	34.7	32.3	21.8	19.0

Table 4

Summary of the Results for Matthew in Each Condition Including Schedule Parameters, Changeover Responses, Time Spent Responding in Each Component, Number of Responses Emitted in Each Component, Number of Delivered Reinforcements in Each Component, and Local Response Rate in Each Component. All data are means of the last five days of exposure to the conditions except for the adaptation sessions, which are the means of the last four days of exposure.

Matthew

	Schedule Parameters in Seconds				
	Adaptation	VI 10 VI 10	VI 10 VI 5	VI 10 VI 20	VI 10 VI 5
Changeover responses	8	11	13	3	11
Time (seconds)					
constant	305	310	244	494	178
changed	182	290	344	46	422
Responses					
constant	155	192	187	391	106
changed	101	188	258	28	225
Reinforcements					
constant	--	24	18	34	15
changed	--	28	54	3	61
Local response rate: resp/min					
constant	30.5	37.2	46.0	52.2	35.7
changed	33.3	38.9	45.0	36.5	32.0

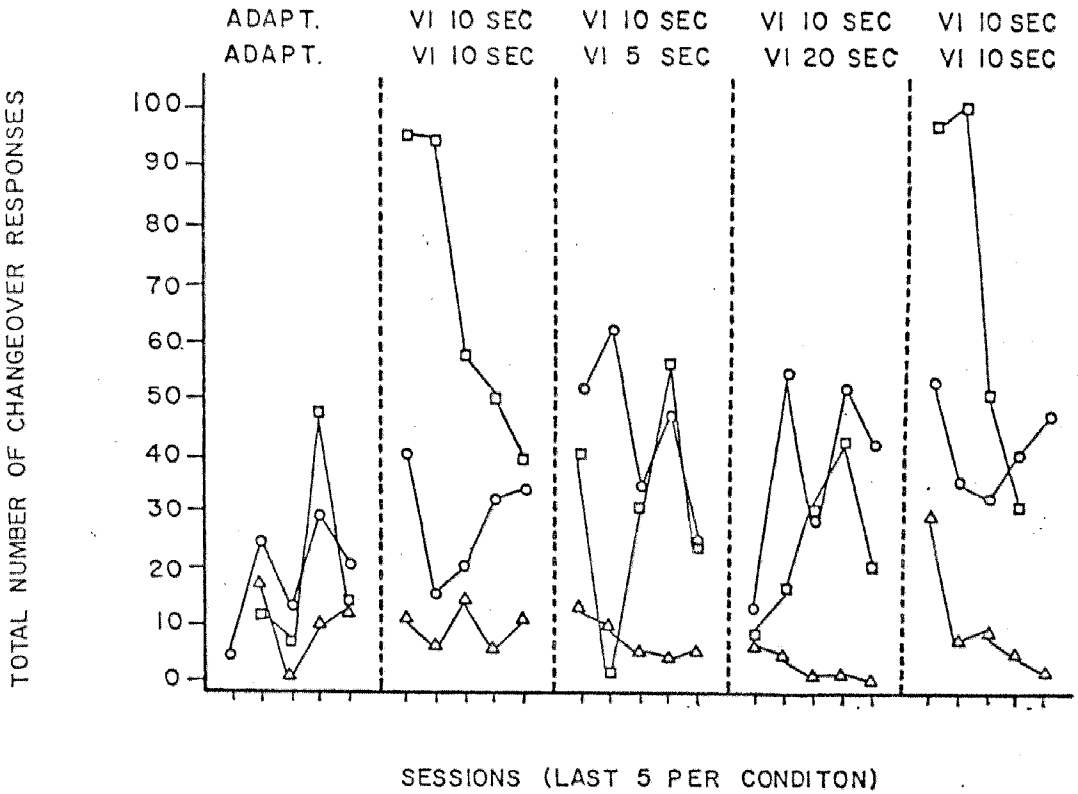

Figure 1. Total number of changeover responses emitted during each session by Meghan (circles), Tera (squares), and Matthew (triangles) as a function of adaptation and four programmed concurrent schedule parameters. Note: the asterick signifies that a concurrent VI 10 sec VI 40 sec schedule was programmed for Meghan in this condition.

All three infants emitted the head turn response during the adaptation phase. However, the degree to which head turns were emitted and maintained varied among infants and between conditions for each infant. For both Meghan and Tera, Figure 1 shows that changeover responding was extremely variable within each condition, with a marked degree of overlap between conditions. Although the mean number of changeover responses emitted during the adaptation phase was less than the mean number of changeover responses emitted during the other phases of the study, no systematic relationship emerged between changeover responding and the programmed schedule parameters.

For Matthew, Figure 1 shows that changeover responding was stable both within and between conditions. The total number of changeover responses emitted by Matthew were extremely infrequent during all conditions relative to the number of changeover responses emitted by Meghan and Tera. The most notable aspect of the data for changeover responses emitted by Matthew occurred during the final session in the conc VI 10 sec VI 20 sec condition in which no changeover responses were emitted. This cessation in changeover responding functioned to maintain exclusive contact with the VI 10 sec component of the schedule. Subsequently, when the schedule was changed to a conc VI 10 sec VI 5 sec schedule, changeover responding increased dramatically, but steadily decreased in frequency in subsequent sessions.

Relative Time Allocation

Figures 2, 3, and 4 show the relative time allocation data for Meghan, Tera, and Matthew, respectively. For each infant, the circles represent the proportion of time spent responding in the constant schedule component (T_1 / T_1 + T_2) and the triangles represent the proportion of time spent responding in the changing schedule component (T_2 / T_2 + T_1) as a function of different concurrent schedule parameters. Examination of the relative time allocation figures for each infant reveals that the proportion of time each infant spent responding in a given concurrent schedule component systematically varied as a function of the programmed availability of contingent mobile movement.

In Figure 2, the relative time allocation data for Meghan is displayed. During the adaptation sessions, relative time allocation was extremely variable, with a marked crossover of data points from session to session. This variability decreased during the conc VI 10 sec VI 10 sec condition, with a slight preference shown for the component associated with the 1200 hz tone. With the implementation of the conc VI 10 sec VI 5 sec condition, more time was spent responding in the changed component which was previously the least-preferred component, the separation between the time allocated to the two components increased, and stability increased eliminating the crossover between components. Altering the conc VI 10 sec VI 5 sec to a

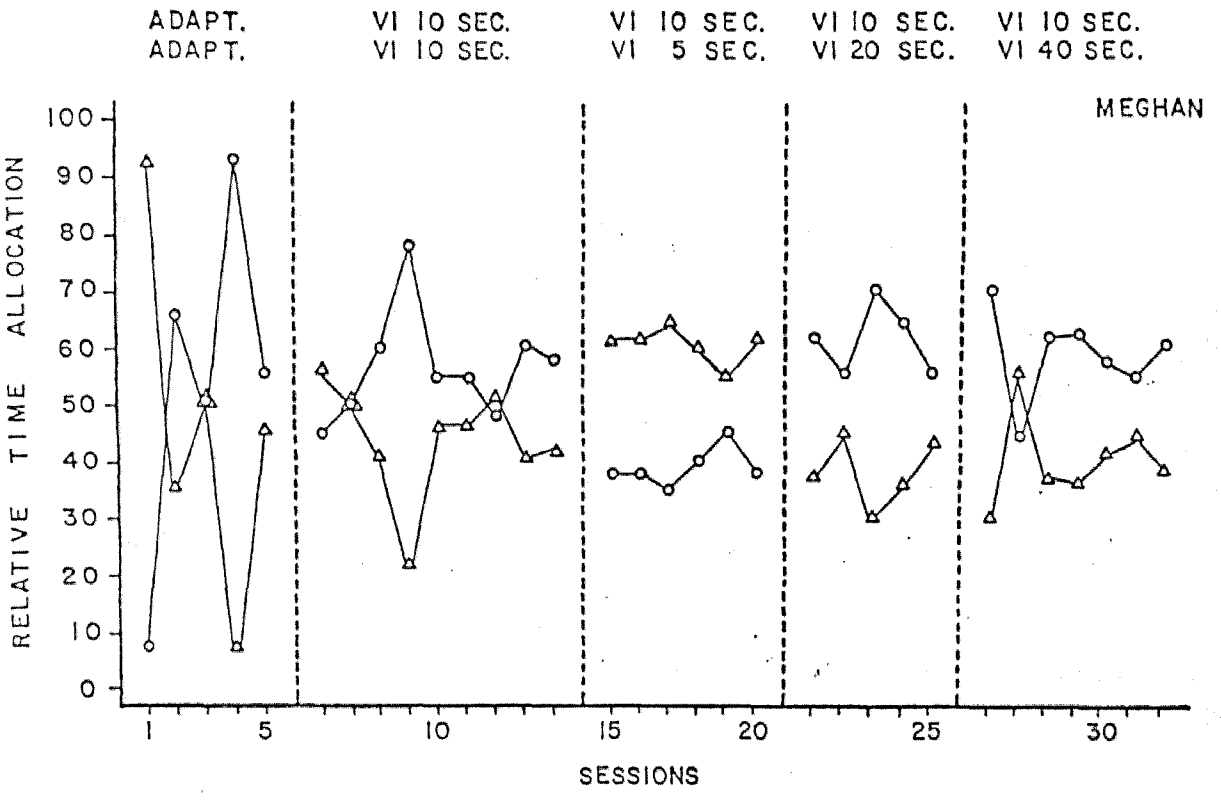

Figure 2. Relative time allocation for Meghan as a function of adaptation and four concurrent schedule parameters. Note: triangles represent the relative time allotted in the constant schedule component (900 hz); circles represent the relative time allotted in the changed schedule component (1200 hz).

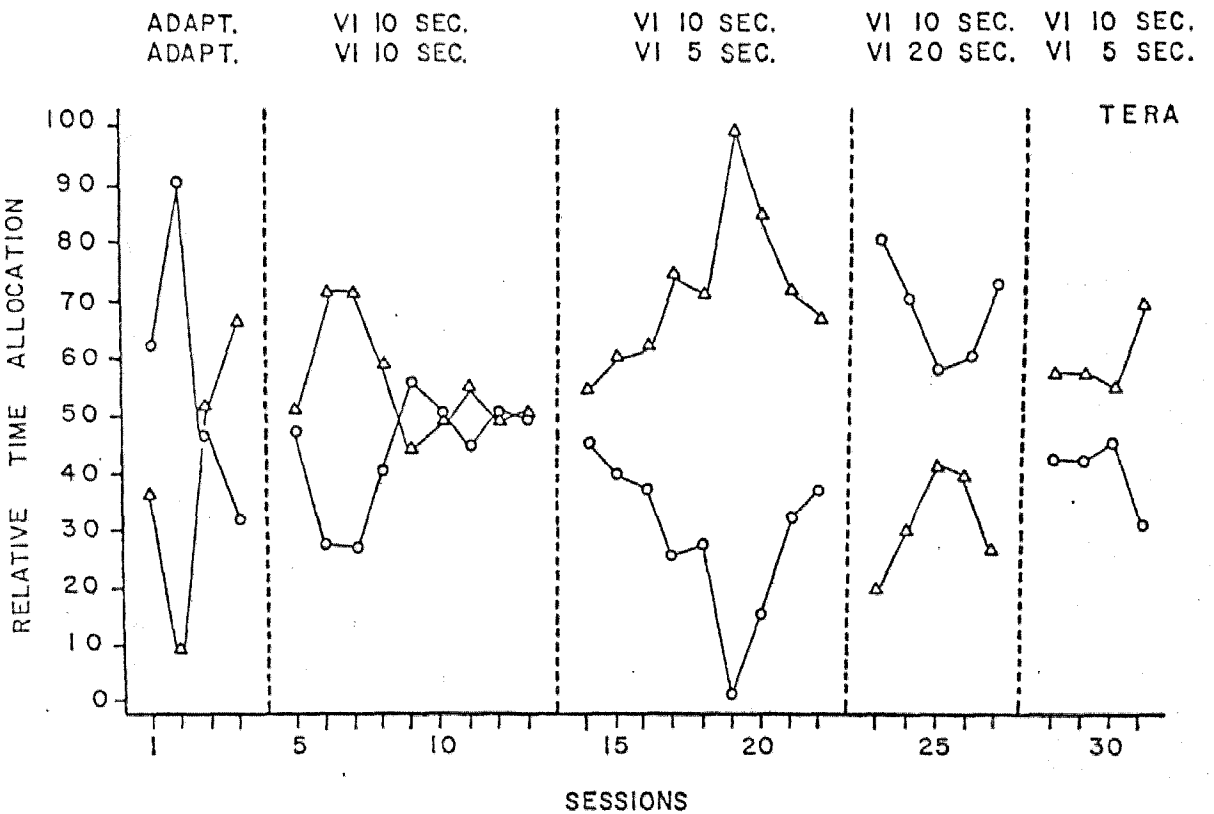

Figure 3. Relative time allocation for Tera as a function of adaptation and four concurrent schedule parameters. Note: circles represent the relative time allotted in the constant schedule component (1200 hz); triangles represent the relative time allotted in the changed schedule component (900 hz).

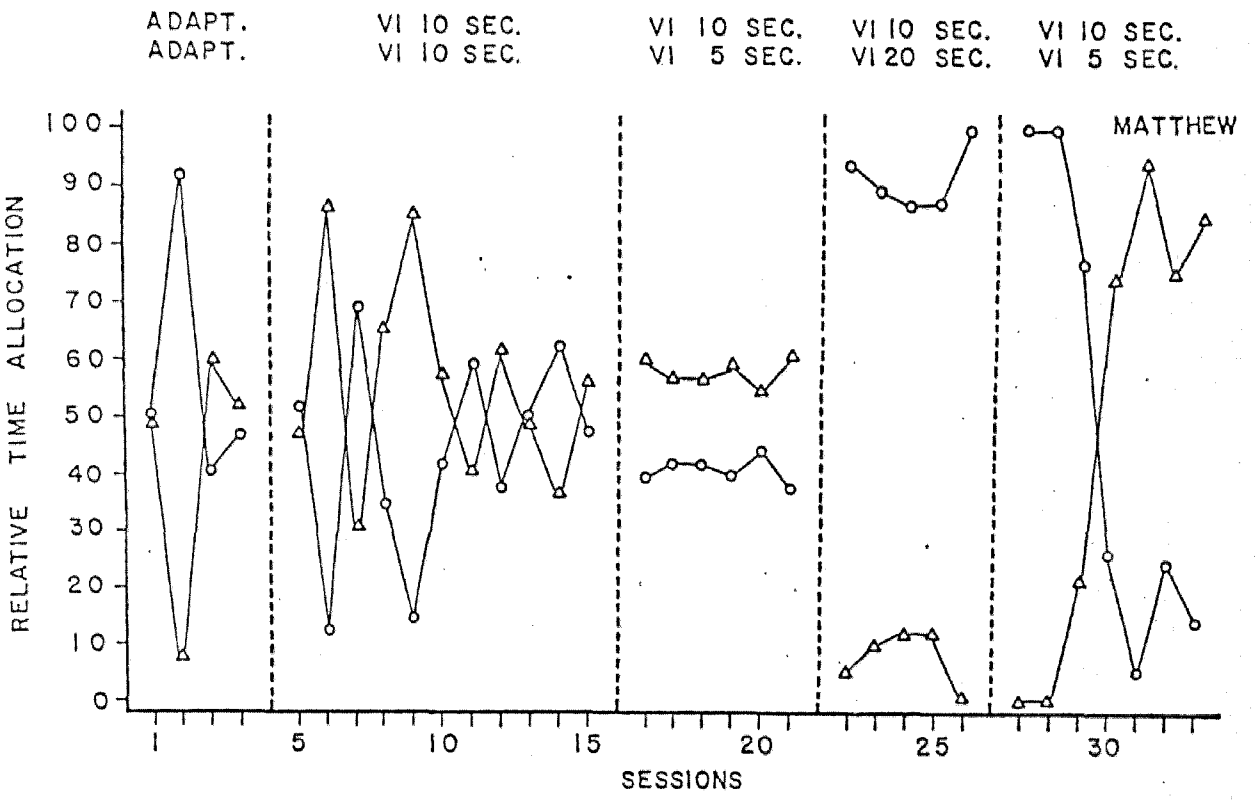

Figure 4. Relative time allocation for Matthew as a function of adaptation and four concurrent schedule parameters. Note: circles represent the relative time allotted in the constant schedule component (1200 hz); triangles represent the relative time allotted in the changed schedule component (900 hz).

conc VI 10 sec VI 20 sec resulted in a reversal in time allocation such that more time was spent responding in the constant component, with a slight increase in variability relative to the previous condition. When the conc VI 10 sec VI 40 sec condition was implemented, more time continued to be allocated to the constant component but the separation in time allocated between the components did not increase as a function of the increased difference in scheduled reinforcement between the two components. In fact, a temporary reversal in time allocation was initially observed.

In Figure 3, the relative time allocation data for Tera is displayed. During the adaptation phase, relative time allocation between components was extremely variable. The variability during the conc VI 10 sec VI 10 sec condition decreased, with no preference for either concurrent schedule component evident. With the implementation of the conc VI 10 sec VI 5 sec condition, a consistent preference for the richer VI 5 sec component paired with the 900 hz tone emerged. The separation between the time allocated to each component initially increased to a point of maximizing, and then decreased. Implementation of the conc VI 10 sec VI 20 sec condition resulted in an immediate reversal in preference, with more time allocated to the constant component. Reintroduction of the conc VI 10 sec VI 5 sec condition resulted in an immediate reversal in time allocation, with less variability than was obtained in this

condition previously. However, the degree of preference displayed for the richer VI schedule component was not as large as had been displayed in the previous conc VI 10 sec VI 5 sec condition.

Figure 4 displays the relative time allocation data for Matthew. During the adaptation phase, relative time allocation between components was variable, with no consistent trend evident. Time allocation during the conc VI 10 sec VI 10 sec condition was initially quite variable over sessions, with crossovers, in terms of which component was in effect the longest, repeatedly occurring. Although this variability decreased over sessions, crossovers continued, with no preference emerging for either concurrent schedule component. With the implementation of the conc VI 10 sec VI 5 sec condition, these shifts in component preference ended, variability decreased, and a consistent preference in time allocation emerged for the VI 5 sec component paired with the 900 hz tone. With the implementation of the conc VI 10 sec VI 20 sec condition, time allocation preference immediately reversed. Additionally, a large preference for the constant VI 10 sec component was evident, reaching total maximizing during the last session of the condition. Initially, the reintroduction of the conc VI 10 sec VI 5 sec condition had no effect on time allocation; all session time was spent exclusively in the VI 10 sec component. However, during the fourth conc VI 10 sec VI 5 sec session, the time

allocation preference reversed, with nearly all time allocated to the VI 5 sec component.

The relative response allocation data for each infant revealed the same schedule control over responding as was demonstrated by the relative time allocation data; that is, the proportion of foot kicks each infant emitted in a given concurrent schedule component systematically varied as a function of the programmed availability of contingent mobile movement. For this reason, the response allocation data are not reported here, inasmuch as they showed the same major effects in every case.

Matching

Figure 5 shows the logarithm of the time ratios (left panels) and response ratios (right panels) as a function of the logarithm of the reinforcement ratios for each subject. The data are displayed such that the measures for the constant component are divided by the measures for the changed schedule component. The solid lines were fitted to the data by the method of least squares, and the dashed lines indicate perfect matching between the distribution of time (or responses) and reinforcements. The equation for the best fitting line and the proportion of the variance this line accounted for is shown in the bottom right corner of each panel. All matching lines are plotted for obtained reinforcement.

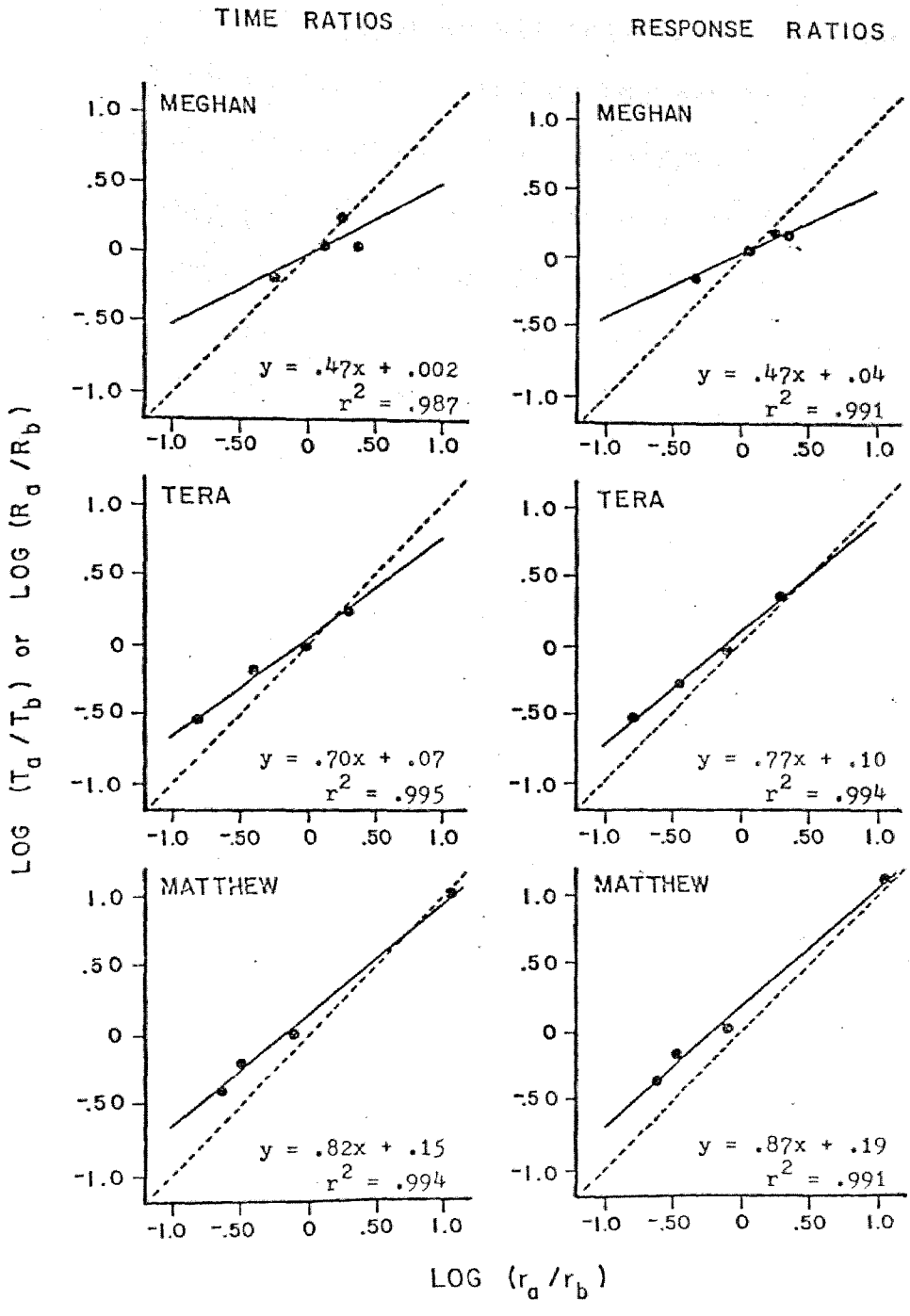

Figure 5. Logarithm of the time ratios (left panels) and response ratios (right panels) as a function of the logarithm of the reinforcement ratios for each infant. The solid lines were fitted to the data by the method of least squares. The dashed lines indicate the locus of perfect matching.

For response and time logarithmic ratios, the slopes of the best fitting lines all fell below, or undermatched, the slope of 1.0 predicted by the matching equation. Two of the infants (Meghan and Tera) displayed a tendency to allocate responses and time equally between the two concurrent schedule components, irrespective of programmed reinforcement. The y-intercepts associated with the time and response allocation figures were positive for all infants. These positive intercepts mean that all infants, to differing degrees, responded more frequently and spent more time in the leaner VI schedule component than would have been predicted by the log-reinforcement ratios. In general, the log-response ratios more closely approximated the slope predicted by the matching equation than did the log-time ratios.

CHAPTER IV

DISCUSSION

The data from the present study demonstrate that the responding of young infants can be systematically controlled by the complex contingencies generated in concurrent schedules of reinforcement. Both the proportion of time each infant spent responding in a given schedule component as well as the number of responses emitted in a given schedule component systematically varied as the programmed availability of contingent mobile movement was varied. In addition, when the logarithm of each infant's response and time ratios were graphed relative to the log-reinforcement ratios, the slope of the best fitted line consistently fell below, or undermatched, perfect matching. To differing degrees, this undermatching seems to result from a tendency to allocate time and responses equally between the two concurrent schedule components, irrespective of programmed reinforcement. Finally, the intercepts for log-response and log-time ratios relative to log-reinforcement ratios were positive for each infant, indicating a consistent bias for the leaner VI schedule component.

Although this study is apparently the first to utilize concurrent schedules of reinforcement in the investigation of infant behavior, the finding that infant behavior is sensitive to complex reinforcement contingencies

has been demonstrated elsewhere (Rovee-Collier & Capatides, 1979; Sheppard, 1969). What makes this study somewhat unique in the infant conditioning literature is its focus on repeated transitions in reinforcement contingencies rather than on shifts between reinforcement and nonreinforcement conditions. In order to demonstrate control in these studies, a response must change in rate when the response is reinforced as compared to when it is not (Clifton, Siqueland, & Lipsitt, 1972; Deitz, 1971; Fagen & Rovee, 1976). The present study demonstrated control by focusing on the shifts in relative time and relative response allocation which occurred as the density of reinforcement in one component of a concurrent schedule was changed relative to the density of reinforcement in the other schedule component. The fact that the relative amount of time allocated in a given concurrent schedule component shifted as reinforcement contingencies were shifted indicates that the head turn response was controlled by the concurrent schedule of reinforcement. However, it was not possible to analyze the response allocation data in isolation from the time allocation data. Since systematic changes in relative response allocation could have been a direct function of the time the infant allocated to each schedule component (Baum & Rachlin, 1969), and since local rates of responding varied unsystematically across both the adaptation and experimental conditions, control over the relative allocation of foot kick responses was not

demonstrated (independent of the time allocated to each component).

A second purpose of this study was to determine whether infant responding would conform to the matching relationship repeatedly demonstrated in studies of older humans and other species. Although the parameter values for individual infants are suspect given the small number and narrow range of reinforcement ratios, in general, the fitted lines obtained from the log-response and log-time ratios are within the range obtained from the literature in studies omitting a changeover delay (Baum, 1974; Bradshaw, Szabadi, & Bevan, 1976; Heyman, 1979). This comparability of matching lines suggests that the matching relationship generalizes to the concurrent schedule performance of well-fed, nondeprived infants.

Although the slopes and intercepts of the matching lines presented in this study are generally within the range of the matching data presented in the animal literature, it would be a mistake to assume that the variables which were the source of the observed bias and undermatching obtained in this study are understood. Some possible explanations for deviations from the locus of perfect matching come from the animal literature, in which a number of possible sources of bias and undermatching have been identified. The sources of bias include: response bias; discrepancy between scheduled and obtained reinforcement; qualitatively different

reinforcers; and qualitatively different schedules (Baum, 1974). Since all of these sources of bias appeared to be controlled for in the present study, it is not apparent which variables were responsible for the bias observed. The variables identified as possible sources of undermatching in the animal literature include: poor discrimination between schedule components (Baum, 1974); too short a changeover delay (Shull & Pliskoff, 1967); inadequate control of deprivation (Baum, 1972); and control, under certain circumstances, by previous experimental conditions (Davison & Hunter, 1979). Any one of these factors, or some combination, may have been the source of the undermatching observed for the following reasons: no changeover delay was used; deprivation levels were not manipulated or controlled; and steady state performance was not always achieved before experimental conditions were changed. It should be noted that the fitted matching lines intersected the theoretical matching lines at a point where the reinforcement rates were equal for two of the subjects but that the slopes were less than the theoretical matching line. Undermatching, in this case, also results in the existence of bias. This questions the assumption that bias and undermatching are independent of each other and under the control of separate variables (Baum, 1974).

A second possible explanation of the observed bias and undermatching is that a history of being "leaned out"

is necessary in order to get closer approximations to perfect matching when reinforcement schedule parameters are relatively lean. Young infants would not have experienced this history. This view is supported by the matching performance of the infants in this study since close approximations to matching were obtained when both schedule components were equal, but deviations from matching were obtained as one reinforcement schedule component was leaned relative to the other component. The observed "overcontrol" of infant responding by the leaner schedule component could have produced the obtained bias and undermatching, and could have important implications for understanding the development of an organism.

Since both explanations presented above are speculative, the general comparability between bias and undermatching outcomes in this study and the animal literature must be viewed with caution. However, the methodology which has resulted in this note of caution is the very methodology which can be utilized to empirically identify the variables which are the sources of bias and undermatching. For example, future research could evaluate whether a pronounced bias results from utilizing qualitatively different reinforcers associated with different concurrent schedule components. Also, the length of changeover delays between concurrent schedule components could be systematically varied in order to determine whether any COD value will result in

better matching. As more of the variables now identified as sources of bias and undermatching in the animal literature are systematically manipulated, perhaps a better controlled methodology for investigating the behavior of infants will develop.

REFERENCES

Baum, W. M. Choice in a continuous procedure. Psychonomic Science, 1972, 28, 263-265.

Baum, W. M. On two types of deviation from the matching law: Bias and undermatching. Journal of the Experimental Analysis of Behavior, 1974, 22, 231-242.

Baum, W. M. Time allocation in human vigilance. Journal of the Experimental Analysis of Behavior, 1975, 23, 45-53.

Baum, W. M., & Rachlin, H. C. Choice as time allocation. Journal of the Experimental Analysis of Behavior, 1969, 12, 861-874.

Bradshaw, C. M., Szabadi, E., & Bevan, P. Behavior of humans in variable-interval schedules of reinforcement. Journal of the Experimental Analysis of Behavior, 1976, 26, 135-141.

Brownstein, A. J., & Pliskoff, S. S. Some effects of relative reinforcement rate and changeover delay in response-independent concurrent schedules of reinforcement. Journal of the Experimental Analysis of Behavior, 1968, 11, 683-688.

Clifton, R., Siqueland, E. R., & Lipsitt, L. P. Conditioned headturning in human newborns as a function of conditioned response requirements and states of wakefulness. Journal of Experimental Child Psychology, 1972, 13, 43-57.

Davison, M. C., & Hunter, I. W. Concurrent schedules: Undermatching and control by previous experimental conditions. Journal of the Experimental Analysis of Behavior, 1979, 32, 233-244.

Deitz, S. Operant behavior in the human infant: Differentiation and discrimination. Unpublished doctoral dissertation, University of Florida, 1971.

deVilliers, P. A. Choice in concurrent schedules and a quantitative formulation of the law of effect. In W. K. Honig & J. E. R. Staddon (Eds.), Handbook of operant behavior. Englewood Cliffs, N.J.: Prentice-Hall, 1977.

Fagen, J. W., & Rovee, C. K. Effects of quantitative shifts in a visual reinforcer on the instrumental response of infants. Journal of Experimental Child Psychology, 1976, 21, 349-360.

Findley, J. D. Preference and switching under concurrent scheduling. Journal of the Experimental Analysis of Behavior, 1958, 1, 123-144.

Heyman, G. M. A markov model description of changeover probabilities on concurrent variable-interval schedules. Journal of the Experimental Analysis of Behavior, 1979, 31, 41-51.

Herrnstein, R. J. Relative and absolute strength of response as a function of frequency of reinforcement. Journal of the Experimental Analysis of Behavior, 1961, 4, 267-272.

Herrnstein, R. J. On the law of effect. Journal of the Experimental Analysis of Behavior, 1970, 13, 243-266.

Huselbus, R. C. Operant conditioning of infant behavior: A review. In H. W. Reese (Ed.), Advances in child development and behavior (Vol. 8). New York: Academic Press, 1973.

Lund, C. A. A reliable, inexpensive device for recording head-turning. Journal of Experimental Child Psychology, 1976, 21, 349-360.

Moffatt, G. H., & Koch, D. L. Escape performance as a function of delay of reinforcement and inescapable US trials. Psychological Reports, 1973, 32, 1255-1261.

Rovee-Collier, C. K., & Capatides, J. B. Positive behavioral contrast in 3-month old infants on multiple conjugate reinforcement schedules. Journal of the Experimental Analysis of Behavior, 1979, 32, 15-27.

Rovee-Collier, C. K., & Gekoski, M. J. The economics of infancy: A review of conjugate reinforcement. In H. W. Reese & L. P. Lipsitt (Eds.), Advances in child development and behavior (Vol. 13). New York: Academic Press, 1979.

Schroeder, S. R., & Holland, J. G. Reinforcement of eye movement with concurrent schedules. Journal of the Experimental Analysis of Behavior, 1969, 12, 897-903.

Sheppard, W. C. Operant control of infant vocal and motor behavior. Journal of Experimental Child Psychology,

1969, 7, 36-51.

Shull, R. L., & Pliskoff, S. S. Changeover delay and concurrent schedules: Some effects on relative performance measures. Journal of the Experimental Analysis of Behavior, 1967, 10, 517-527.

Watson, J. S., & Ramey, C. T. Reactions to response-contingent stimulation in early infancy. Merrill-Palmer Quarterly, 1972, 18, 219-228.

Weisberg, P. Operant procedures for the establishment of stimulus control in two year old infants. Journal of Experimental Child Psychology, 1969, 7, 81-95.